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~ Onlinebeampositionmonitoring ~

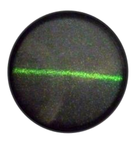
A new compact Design of a three-dimensional Ionization Profile Monitor (3D-IPM).

Introduction

To ensure smooth operation of the free electron laser FLASH at DESY Hamburg, numerous detectors are necessary for the precise measurement of the electron and laser beam. The great advantage of the here described Ionization Profile Monitor (IPM) is the unintrusive determination of the position and intensity distribution of the laser beam.

Measuring principle of an Ionizing Projection Monitor (IPM)

The FLASH laser beam has a variable wavelength from 4.1 to 45 nm, and is located in an Ultra High Vacuum (UHV) beam pipe. Despite the vacuum a certain amount of residual gases still remain. If the laser beam hits a residual gas atom, it becomes ionized and electrons and ions are created. By means of a homogeneous electric field, these electrons and ions can be accelerated in a rectilinear way towards a micro-channel plate (MCP). Here, the impacting particles create an avalanche of secondary electrons in the micro tubes of the MCP, and are visualized on the phosphor-screen. This results in an image of the intensity-dependent laser beam profile (see Figure below).

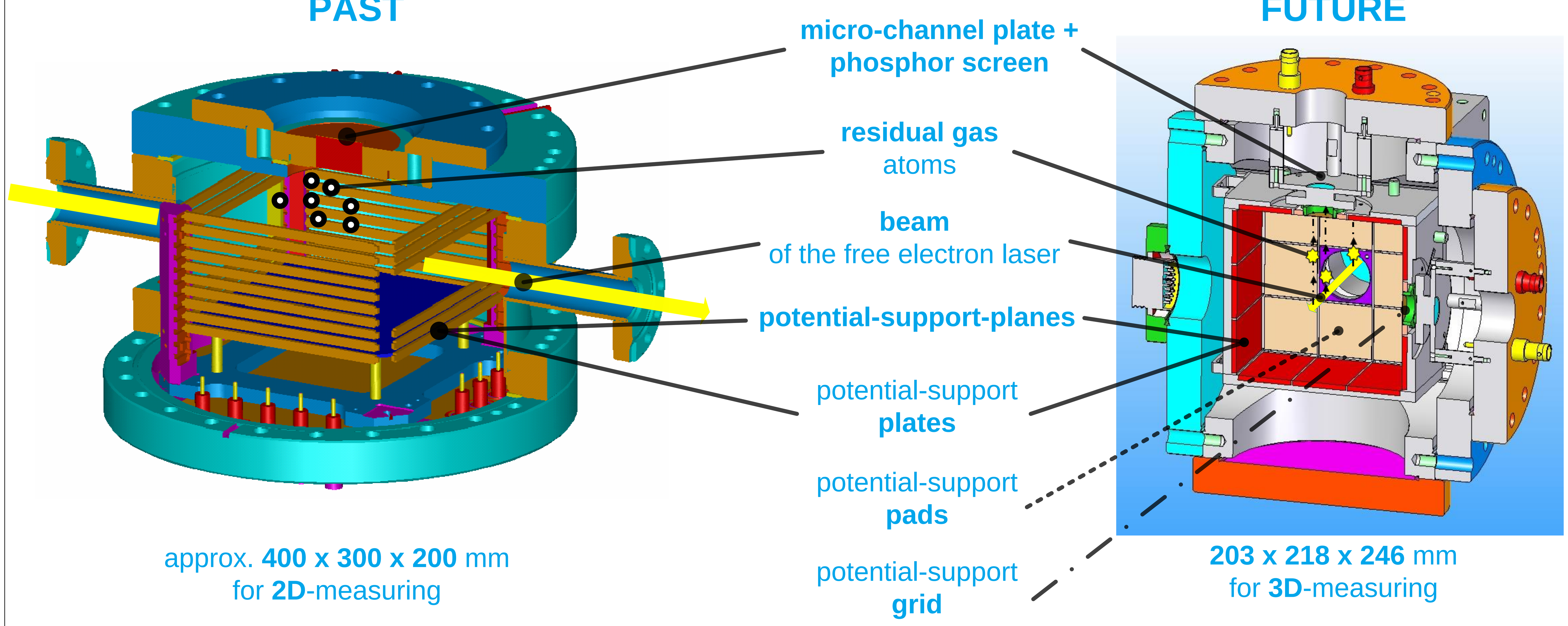


Conventional Set Up

The figure on the right shows an IPM module for the laser beam position measurement as implemented in FLASH. Problems and disadvantages of this design are the following:

- **large size**
- **2 detectors needed** for monitoring horizontal and vertical parameters
- **costly high voltage** feedthroughs (U_{max} = 3'000 V)
- **uncertainty** concerning the homogeneity **of** the **electric field**
- can't take a look on the bunches, **temporal resolution: 1 ms**

PAST | FUTURE



approx. **400 x 300 x 200** mm for **2D**-measuring

203 x 218 x 246 mm for **3D**-measuring

New Design

- **unification** of the horizontal an vertical monitors **by alternating** the **electric field**
- **shielding** of the area of interest to ensure an optimal homogenous electric field
- **compact design** permits **low voltage** (U_max = 600 V)
- low voltage consequences
  - **easier to handle & manufacture**
  - **easier to switch**
  - **cost effective**
- **5** potential-support-**planes**
- **simulation** & analysis **of electric field &** resulting **particle trajectories** with FEM
- FEM offers
  - **optimization of** the **voltage** values **for** linear particle trajectories and **accurate beam imaging**
  - **recursive determination of** the **beam positon**
- **temporal resolution on the order of 100 ns** by using a fast resolving screen

A NEW DESIGN OF THE IONIZATION PROFILE MONITOR

In order to tackle the challenges described above the following design is proposed:

- Unification of the separate horizontal and vertical monitors with an alternating homogeneous electric field.
- A special cage protects the area of interest from electrical stray fields to ensure an optimal homogenous electric field.
- Decreasing the size of the device to 203 mm x 218 mm x 246 mm while at the same time reducing the applied electrical voltage with the appropriate low cost feedthroughs.
- With the Finite Element Method (FEM) a comparison of different residual gas particles is performed concerning their trajectories in the electric field.
- This procedure offers an optimization of the design by simulating the trajectory of the particles in the electrical field with the deflection caused by the inhomogeneity of the field. Varying the CAD monitor model helps finding out the best possible determination of the laser beam position.

Following the principles described above in the figure top right the resulting new design of a 3D detector is presented. The inner cage with a measure of 100 mm x 100 mm x 100 mm consists of equally sized pads, plates and two 28 mm diameter holes for the passage of the beam. The figure shows that 30 different electrical potentials are needed to achieve a homogeneous field.

Device Specifications

The following parts were chosen:

- 1x stainless steel block with measures 203 mm x 218 mm x 246 mm
- 2x reducing flange 160 to 100
- 2x special reducing flange 100 to 40 with electrical feedthroughts
  - SPE-10046425-10 [6]
- 1x CF160 flange
- 1x CA100 flange
- 2x special coated sight glass
  - VPCF40DUVQ-L-BBAR2 [6]
  - Fused Silicia with anti-reflective coating
  - transmission range: 400 nm - 800 nm
- 1x 41-time electrical feedthroughts with plugs and cables
  - W-MPC2-41-DE-CE-SSG [6]
- 2x micro-channel-plate and P47 phosphor screen assembly by HAMAMATSU
  - F2222-27P227 [4]
- 2x grid bonded in a ring washer by Precision Eforming
  - MN49 bonded to 20mm SS Frame [7]
- potential support plates and pads consisting of stainless steel
- an inner retainer of the cage consisting of MACOR by MCI UG [9]
- a pulse generator for generating an alternating orthogonal electrical field
  - Matrixpuls 1x21 by
  - GBS ELEKTRONIK GmbH
  - able to grant 100 kHz [8]
- Cameras, which could be chosen by user, but should have a fast shutter time (for example 100 ns) and a high frame rate to achieve a bunch resolution

FINITE ELEMENT IN ELECTROMAGNETIC

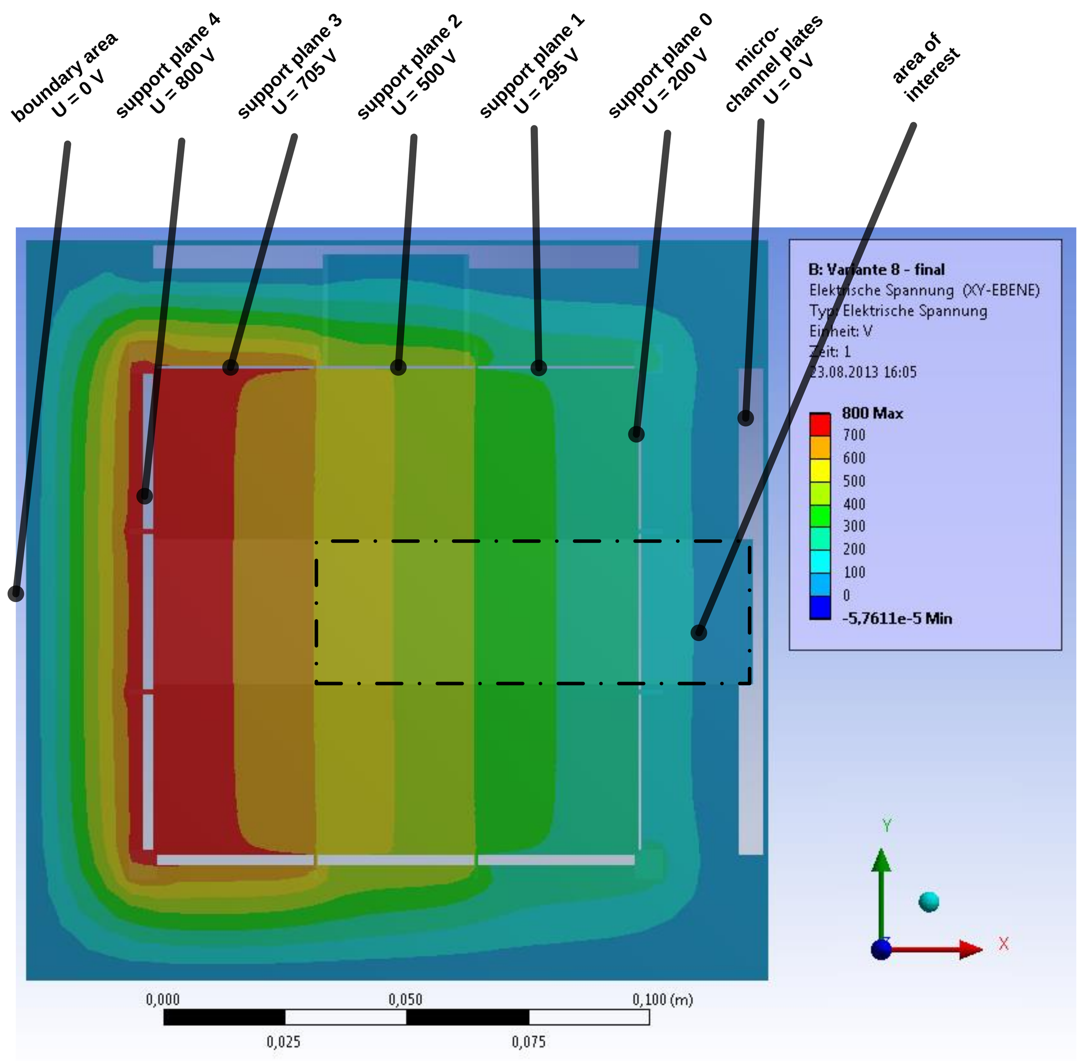
To analyse the homogeneity of the electric field and to determine the trajectory of different particles obtained with the design described above, a FEM analysis was carried out using ANSYS 14 modules workbench and classic. In the simulations different variations and possible future developments of the design were included directly from the CAD-model.

Potential ratios

Simulation studies performed with the workbench module package proved the potential ratios, as can be seen in the bottom figure, to be optimal for a homogeneous electric field and hence for a straight flight of particles. Since the MCP has a diameter of merely 20 mm, only in the marked "area of interest" the electric field must be homogeneous. Also, the expected beam variation in X or Y is below ± 5 mm. Homogeneity in a larger space does not result in a higher spatial resolution.

The electrically conductive potential supporting points are assumed as being an ideal conductor with equal potential at any point.

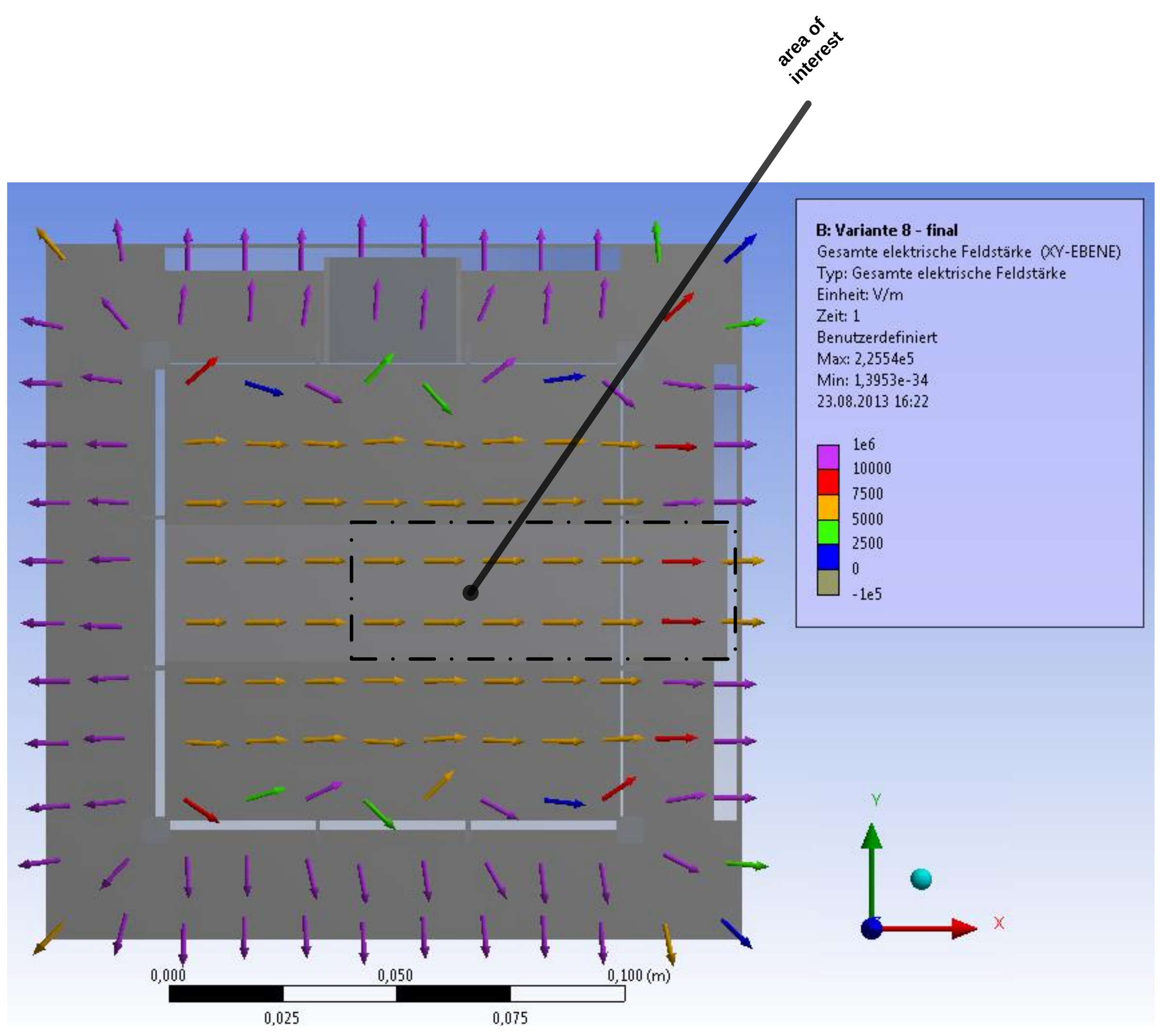
The permittivity of the ceramic was assigned to $\varepsilon = 6$ and of the vacuum to $\varepsilon = 1$.



Electric Field Strengths

The homogeneity of the electric field could be shown best by a figure electric field lines.

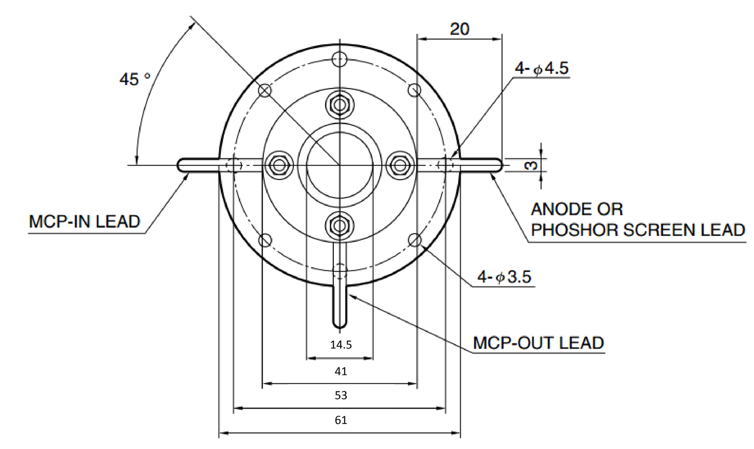
The equipotential lines correspond directly to the electrical field lines, as can be seen on the bottom figure. Inside the cage, in the area of interest, the vectors of the electric field lines are absolutely straight. Outside of the cage the lines are nearly straight, but not so unlinear to be harmfull. The user has to know, that when the figure of the beam it over the middle of the cage, there is a very small offset between the beam position and the figure.

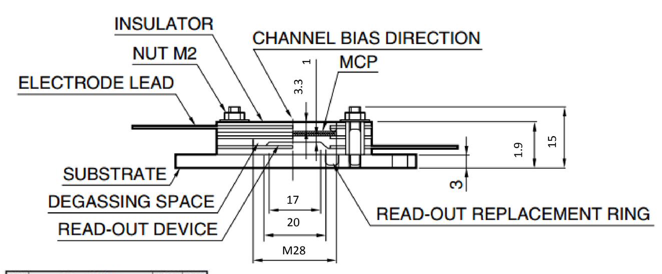


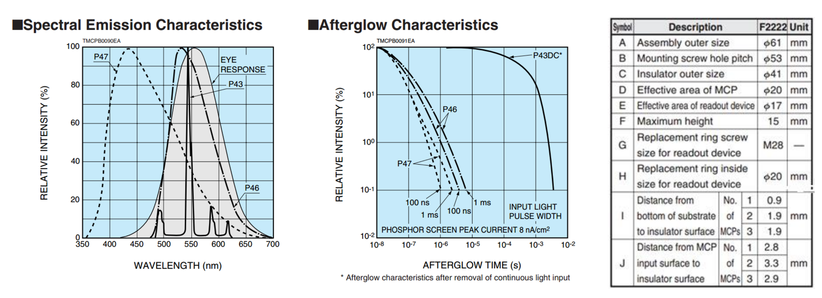
Special Features

MCP and phosphorscreen assembly

- double MCP
- MCP-channel-diameter: 6 µm
- channel gap: 7.5 µm
- phoshorscreen typ: P47
- peak emission wavelenght: 430 nm
- emission color: blue
- 10 % afterglow time: 110 ns







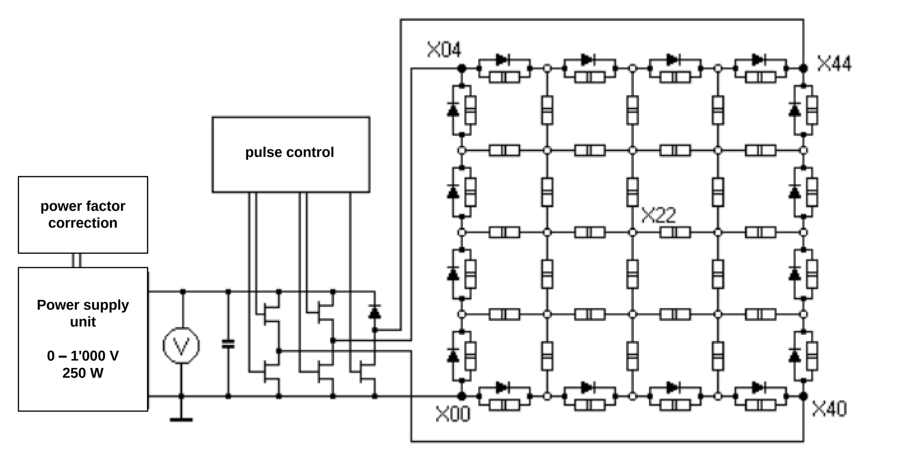
All figures of point „MCP and phosphorscreen assembly" are courtesy of „Hamamatsu Photonics K.K."

41-time electrical feedthroughts

- max. 1'000 V
- Max 3 A
- easy plug and play

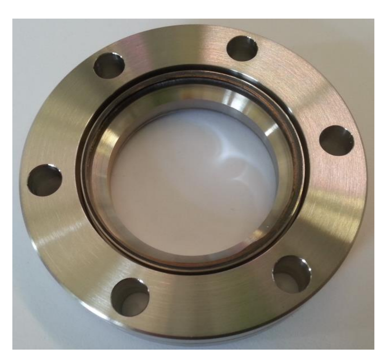
pulse generator

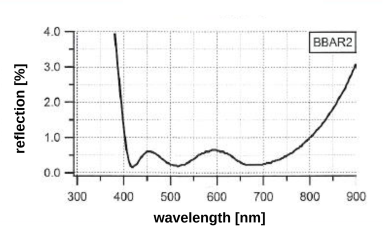
- f_{max} = 100 kHz
- Max. 1'000 V



special coated sight glass

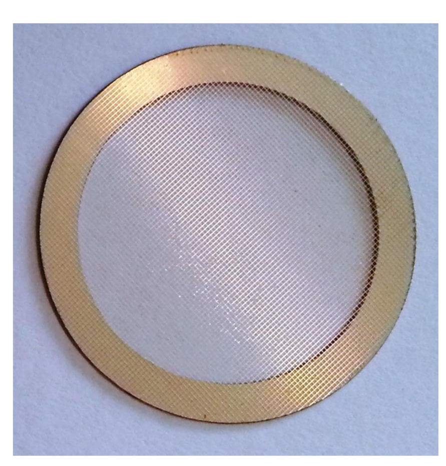
- VPCF40DUVQ-L-BBAR2
- Fused Silicia with anti-reflective coating
- transmission range: 400 nm - 800 nm





grid bonded in a ring washer

- 2117,6 wire / inch (2'987.04 wire / mm)
- space: 0.005 inch (0.0127 mm)
- wire: 0.0005 inch (0.2032 mm)
- transmission: 88.6 %



CONCLUSION

The first prototype of a 3D-IPM is currently under construction and will be completed and tested in 2013. Before any test with a toggling electrical field, there will be tests with a rigid field. First practice tests are planned in 2014 at FLASH in DESY Hamburg site.

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